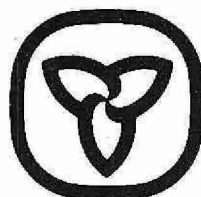


Sulphur Dioxide (1972) - Heavy Metal (1971) Levels and Vegetative Effects in the Wawa Area



Ontario

Ministry of the Environment

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Sulphur Dioxide (1972) - Heavy Metal (1971)
Levels and Vegetation Effects in the Wawa Area

By

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Sudbury, Ontario
April, 1973

Table of Contents

- I. Sulphur dioxide levels in the Wawa area during 1972
 - (a) Introduction
 - (b) SO₂ levels recorded in the town of Wawa
 - (c) SO₂ levels recorded at Goudreau
 - (d) Use of low sulphur content ore
- II. Injury to vegetation by SO₂ during 1972
- III. Wawa area vegetation study plots
 - Program Outline
 - Observations:
 - (a) Tree crown condition
 - (b) Plant population studies
 - (c) Chemical analysis of 1971 vegetation and soil samples
 - (d) Lead Peroxide Candle Survey
- IV. Conclusions
- V. Acknowledgments
- VI. Appendix (Figures and Tables)

Summary

During the 1972 growing season (mid May to mid September), the Air Management Branch of the Ontario Ministry of the Environment operated a network of instruments in the Wawa area to measure ground level concentrations of SO_2 emitted from the sintering operations of the Algoma Ore Division, The Algoma Steel Corporation Ltd. at Wawa. The network was made up of two continuous SO_2 monitors and eight lead peroxide candles.

Sulphur dioxide was recorded at Goudreau (22 miles northeast of Wawa) 26.2% of the time during the 1972 season. The maximum half-hour concentration for the season was 0.32 ppm. Only 0.8% of the half-hour readings were above 0.25 ppm.

Sulphur dioxide was recorded only 4% of the time in the Town of Wawa during 1972. Concentrations of SO_2 in excess of 2.00 ppm were recorded in October and this is the first season levels in excess of 2.00 ppm have been recorded.

While vegetation injury by SO_2 was not as widespread in the Wawa area during the 1972 season as in previous seasons, trace to severe visible injury did occur on several tree species and species of ground cover vegetation over about a sixty square mile area to the northeast of Wawa. The most severe injury occurred on white birch, trembling aspen, alder, jack pine, showy mountain ash and dogwood, in the vicinity of vegetation study plots 1, 2, 3 and 4 (see Fig. 1). Some degree of visible injury to vegetation was observed as far as 15 miles to the northeast of Wawa. Most of the injury occurred during the months of July and August.

In 1969, six surveillance plots and two control plots were established to monitor the effects of sulphur dioxide on the vegetation in the area to the northeast of the sinter plant. At each plot, 10 trees and 10 shrubs were tagged and the crown condition and insect, disease and SO_2 injury were recorded. Also two ground cover vegetation grids for the measurement of plant populations were set out adjacent to each plot. A lead peroxide candle, to measure ambient levels of sulphur dioxide, was also located at each plot. These plots have been inspected at monthly intervals from May to October, from 1969 to 1972. In 1970 a program of sampling the vegetation and soil for chemical analysis was initiated. These samples were analysed for total sulphur, arsenic, iron and zinc.

At plots 1 and 2 (10 and 12 miles northeast of the sinter plant), injury to vegetation by SO_2 , sulphation rate measured on the lead peroxide candles, deterioration of the crown condition, and contamination of the vegetation and soil by sulphur, arsenic and iron were exceedingly high. From plot 3 to 6 (16 to 24 miles northeast of the sinter plant), the levels of these parameters decreased accordingly with increased distance from the plant.

Vegetation sampling and air monitoring will be continued through the 1973 growing season and a close surveillance of the forest communities will be maintained to determine the effects of the sinter plant operation on the environment in the Wawa area.

I. Sulphur Dioxide Levels In The Wawa Area During 1972

(a) Introduction

In 1961 the Ontario Department of Mines set up a network of instruments to measure the ground level concentrations of sulphur dioxide emitted from the sinter operations of the Algoma Ore Division, The Algoma Steel Corporation Ltd., at Wawa. The network consisted of 8 sulphation candles and one Thomas autometer.

The autometer was set up at Goudreau 22 miles northeast of Wawa and the candles at locations in all directions from the sintering plant. Since 1961 the instruments have been operated each year during the growing season (mid May to mid September). In 1969 another autometer was set-up in the town of Wawa to measure the ground level concentrations of SO₂ in the town.

Vegetation study plots were set up in 1969 to give a more complete picture of the environmental impact of the fumes, with regard to forest tree growth and ground cover vegetation populations. Six plots were established in the Fume Damage Area and two at control locations. In some cases, the locations of the original sulphation candles were changed slightly to coincide with the plot locations (Fig.1).

The results of the monitoring program and the occurrence of vegetation injury has been reported to the Special Sulphur Dioxide Committee annually, since 1962.

After the repeal of the Sulphur Fumes Arbitration Act in 1970, the responsibility of maintaining the monitoring network and vegetation studies was transferred to the Air Management Branch of the Department of Energy and Resources Management. In 1972 the various Government Departments were organized into Ministries and since then, the Air Management Branch of the Ministry of Environment has maintained the Wawa area monitoring network and conducted vegetation studies in the Wawa area.

(b) Sulphur Dioxide Levels Recorded In The Town Of Wawa During 1972

One Thomas autometer was operated at 29 Hillcrest Avenue, Wawa, from May 24th to October 26th. During this period, valid data was collected for 85.8% of the time. The SO₂ levels recorded at this location for the growing seasons of 1969 through 1972 are shown in Table 1 of this report.

During the 8 days the recorder was operated in May, three fumigations occurred, however, only one fumigation occurred during daylight hours and the intensity of this three hour fumigation was calculated to be 46. The intensity of a fumigation is a factor which combines the concentration and duration of a fumigation. The intensity factor is based on average daytime concentration over periods of 1, 2, 4, and 8-hour intervals. Observation made over the years have indicated that most vegetation injury by SO₂ occurs when the following SO₂ levels are reached or exceeded:

0.95 ppm for 1 hour
or 0.55 ppm for 2 hours
or 0.35 ppm for 4 hours
or 0.25 ppm for 8 hours

Any fumigation with any of the above combinations of concentrations and durations would be assigned an intensity of 100. The maximum half-hour concentration during the month was 0.55 ppm and this occurred during daylight hours on May 31 (Table 2).

Zero readings accounted for 98% of the total readings during June. The average concentration of SO₂ for the entire month was less than 0.01 ppm (see Table 1). Only one fumigation occurred during daylight hours and the intensity of this fumigation was 23.

Valid SO₂ data was collected for 99% of the time during July 1972 at Wawa and zero readings accounted for 98% of the total. Sulphur dioxide was recorded during daylight hours on five days during July.

On July 28th a $4\frac{1}{2}$ hour fumigation of SO₂ occurred in Wawa. The intensity of this fumigation was 25 and it was the highest intensity calculated for any fumigation during the month. The maximum half-hour concentration was 0.26 and this was part of the $4\frac{1}{2}$ hour fumigation which occurred on July 28th.

Sulphur dioxide was recorded for only 4.4% of the time during August. A total of 65 positive readings were taken and all but one were less than 0.25 ppm. A three and one half hour fumigation which occurred on August 12th had a calculated intensity of 26 and this was the highest factor calculated for any fumigation during the month.

During September, SO₂ was recorded 3.7% of the time at Wawa. No potentially injurious fumigations occurred during the month and the average SO₂ concentration for the month was 0.04 ppm.

There were 15 half-hour readings over 1.00 ppm at Wawa during October 1972. A concentration of 2.03 ppm occurred on October 17 and this is the highest half-hour concentration ever recorded at Wawa. Three fumigations with intensities over 100 occurred during the month of October. A fumigation with an intensity of 267 occurred on October 8 and this is the highest ever recorded at Wawa.

(c) Sulphur Dioxide Levels Recorded At Goudreau During 1972

A sulphur dioxide monitor was operated at Goudreau, 21.6 miles northeast of Wawa, from May 24th to September 30th. Valid data was collected for almost 80% of this period. Unusually low temperatures during the month of October resulted in several equipment breakdowns and consequently, no valid data was collected during October.

During the 8 days the recorder was operated during May, SO₂ was recorded 17.12% of the time (see Table 3). The maximum half-hour concentration was 0.15 ppm and the maximum intensity for a daytime fumigation was 34 (Table 4).

Fumigations of SO₂ were recorded during daylight hours on ten days during June. The maximum intensity was 18 and this was calculated for a fumigation which occurred on June 3rd. A total of 164 half-hour SO₂ concentrations were recorded and these were all less than 0.10 ppm.

During July, SO₂ was recorded during daylight hours on 20 days. The maximum intensity for the season, 60, was calculated for a fumigation which occurred on July 4th. Sulphur dioxide was recorded at Goudreau almost 40% of the time during July. Most of the concentrations were less than 0.10 ppm with only two half-hour readings over 0.25 ppm. Southwest winds accounted for about 57%, (see Table 5), of the total during the month. Usually southwest winds account for about 30% of the total during August in the Wawa area. The high frequency of southwest winds would account for the correspondingly high frequency of SO₂ fumigations at Goudreau.

Sulphur dioxide was recorded at Goudreau 39% of the time during August. Of the total 485 positive readings which were measured, 474 were less than 0.10 ppm and only two were greater than 0.25 ppm. The maximum half-hour concentration for the season 0.32 ppm, was recorded on August 10th. This fumigation had an intensity of 35, which was the maximum for the month of August.

Valid data was collected for 93% of the time during September. A total of 251 half-hour SO₂ concentrations were recorded and they were all less than 0.25 ppm. The maximum half-hour concentration was 0.10 ppm. The maximum intensity for the month was 16 and this was for a fumigation which occurred on September 1, 1972.

(d) Use of Low Sulphur Content Ore

In 1961 the Algoma Ore Division began a program whereby selected low sulphur content ore was used during the growing season, (mid May to mid September), and the higher sulphur content ores during the non-growing season. The program has continued each growing season since 1961. During the 1972 season, the average sulphur content of the ore was 3.33%. A total of 622,332 gross tons of sinter were produced from 926,164 gross tons of ore (Figs. 2&3, Table 6). A total of 30,342 gross tons of sulphur was emitted as SO₂ during the 1972 season. In the table below, the monthly production schedule is shown:

Month	Gross Tons of Ore	% of Sulphur in Ore	Gross Tons of Sulphur Lost as SO ₂
May 16-31	127,770	3.39	4,247
June	250,621	3.32	8,181
June	220,839	3.39	7,370
August	232,365	3.29	7,513
Sept. 1-15	94,569	3.27	3,031
TOTALS	926,164		30,342

II. Injury to Vegetation by SO₂ During 1972

Vegetation was injured by SO₂ on several occasions in the Wawa area during 1972. While the injury was not as **widespread as** in some of the previous seasons it was more severe in the area about 15 miles northeast of the sinter plant.

No visible vegetation injury was observed in the town of Wawa. In previous seasons some degree of injury has been observed in the town. No potentially injurious fumigations occurred in Wawa during June, July, August or September. In October three potentially injurious fumigations occurred. The intensities of these fumigations were 267, 207 and 186. If these fumigations had occurred earlier in the growing season, severe injury would probably have occurred.

Vegetation was not injured by SO₂ in the Wawa area during May. Other agents such as frost and insects caused severe injury to deciduous trees and shrubs.

During June, trace (0-5% of leaf area damaged) SO₂ injury occurred on trembling aspen and white birch in an approximately five square mile area west of the sinter plant. No injury was observed in the area to the northeast of the plant during June.

During July, light (6-15% of leaf area damaged) to moderate (16-35% of leaf area damaged) injury occurred on trembling aspen, white birch, pin cherry, showy mountain ash and dogwood, in an approximately 25 square mile area northeast of the plant. This is the area where vegetation study plots 1, 2 and 3 are located.

During August, severe injury (more than 35% of leaf area damaged) occurred on white birch in the area where plots 1, 2, 3 and 4 are situated. Light to moderate injury occurred on trembling aspen, showy mountain ash, alder, dogwood, pin cherry, jack pine, raspberry, bracken fern and fireweed. Vegetation over about a 60 square mile area was damaged to some degree during August.

No SO₂ injury was noted in the Wawa area during September or October of 1972.

No injury was noted in the vicinity of plots 5 (22 miles northeast of plant) and 6 (24 miles northeast of plant) during 1972. In previous seasons, injury has occurred in the vicinity of these plots. The maximum intensity of any fumigation recorded in this area during the season was only 60 and this occurred on July 4th. The maximum intensity of any fumigation during May was 34, June 18, August 35 and September 17.

III Wawa Area Vegetation Study Plots - Program Outline

In 1969, the Phytotoxicology Section of the Air Management Branch in co-operation with the White River District of the Ministry of Natural Resources established six surveillance plots in a transect line northeast of the sinter plant and two control plots located outside the Fume Damage Area (35 miles from the sinter plant) as follows:

Plot #1 Location: Parks Lake located in the "Total Kill" section of the Fume Damage area 10 miles northeast of the sinter plant.

Site Description: Open, low shrubby area, few (20') trees; rocky outcrops, soil thin, vegetation sparse in exposed sites, dense in protected, damp sites; many grassy or "weedy" glades.

Plot #2 Location: Finger Lake located in the "Total Kill" section of the Fume Damage area 12 miles northeast of the sinter plant.

Site Description: Low trees and shrubs canopy; shrubs dense; rocky outcrops, soil thin, little humus; similar to Plot #2.

Plot #3 Location: Perry Lake located in the "Heavy Kill" section of the Fume Damage area 16 miles northeast of the sinter plant.

Site Description: Dense spruce-fir canopy, trees 30' tall, thick humus layer, few rock outcrops, many seedlings.

Plot #4 Location: Garbe Lake located in the "Heavy Kill" section of the Fume Damage area, 19 miles northeast of the sinter plant.

Site Description: Open spruce-birch canopy; thin humus, medium to dry soil, many rocky outcrops.

Plot #5 Location Goudreau townsite located in the "Light Damage" section of the Fume Damage area, 22 miles northeast of the sinter plant.

Site Description: Dry open woods with aspen predominating on a south slope, disturbed site, many "weedy" species.

Plot #6 Location: Herman Lake located in the "Light Damage" section of the Fume Damage area, 24 miles northeast of the sinter plant.

Site Description: Small island, disturbed by habitation; white birch dominating, open, low shrub cover; many "weedy" species, gravelly lake shore.

Plot #7 Location: Control plot located outside the Fume Damage area near Crouche Lake, 38 miles northeast of the sinter plant.

Site Description: 20° slope with a southern exposure; soil thin, dry; abundant litter; canopy open; trembling aspen and maple dominant.

Plot #8 Location: Control plot located outside the Fume Damage area in Obatanga Provincial Park, 35 miles northwest of the sinter plant.

Site Description: Mixed habitat; spruce and fir canopy, boggy area, lake edge; abundant soil moisture, rich humus layer; canopy recently opened by wind throw.

(see Fig. 1 for plot locations)

Note: The terms, Fume Damage Area; Total Kill; Heavy Kill; and Light Damage, refer to the designations assigned to the various areas by the Ministry of Natural Resources during their aerial surveys of the region to assess the impact of the sinter plant fumes on white birch in the area.

When the surveillance plots were established in 1969, 10 trees (trembling aspen and/or white birch) and 10 shrubs (showy mountain ash, mountain maple, prairie willow, red osier dogwood, elderberry, pin cherry, speckled alder, beaked hazel, or serviceberry) were tagged in a 66 ft. x 66 ft. area at each plot. The "crown condition" of the trees was recorded along with insect, disease, or sulphur dioxide injury in order to establish a history of the vegetation on the plots. These conditions were again observed in June, July, and August in 1970, 1971, and 1972. As well, in September of each year the heights and diameters of the tagged trees were recorded for use in growth studies.

At each plot, two 3.3 ft. x 3.3 ft. ground cover vegetation grids were established and the number and species of each type of plant found on these grids were recorded to determine any differences in populations with distance from the sinter plant and any future fluctuations in plant populations. These grids were re-examined in August of 1970, 1971, and 1972.

A program of sampling the vegetation and soil for chemical analysis was also initiated in 1970. Leaf samples from trembling aspen, white birch, mountain maple (or substitute); forage and soil were collected from each of the plots in June, July, August, and September and analysed for fluoride, total sulphur, arsenic, iron, and zinc. This sampling was continued in June, July, and August of 1971 and 1972. Analysis of fluoride was not continued when the 1970 analysis showed that this element was not found to be a problem in the Wawa area.

In 1970, a lead peroxide candle, to measure ambient levels of sulphur dioxide, was set out at each of the vegetation plots and these candles were exchanged at monthly intervals throughout the 1970, 1971, and 1972 growing seasons.

Observations

(a) Tree Crown Condition

The "crown condition" classification system employed was one developed by the Canadian Forestry Service for hardwood species in Ontario. A classification gradation from 1A (healthy) to 6B (dead), with several intermediate conditions, allows for an informative description of the crown condition at the time of surveillance.

Table 7 shows the changes in the "crown conditions" from 1969 to 1970, from 1970 to 1971 and from 1971 to 1972 at each of the eight vegetation plots in the Wawa area. From 1969 to 1971 there was a trend of general improvement which has been attributed to the fact that there were lengthy shut-down periods during the 1969 and 1970 growing seasons. In 1971 however, there were no shut-downs and the greatest amount of SO₂ since 1961 was released from the sinter plant. Again in 1972, heavy emissions of SO₂ were encountered in the Wawa area. This is reflected in the fact that the number of improving crowns decreased and the number of declining crowns increased. Also one more tree died at Plot #1 from 1971 to 1972. The number of trees which improved their crown conditions on the two control plots also decreased, as did the number which declined. This means that, at the control plots, a relatively steady state has occurred. Continued heavy emissions will force further declines in the crown conditions of the trees and shrubs on the plots in the fume damage zone.

(b) Plant Population Studies

The recording of the vegetation populations in the two grids established adjacent to each of the eight Wawa plots has been in progress for four growing seasons (1969, 1970, 1971, 1972). A minimum of five years data is required before meaningful statistical analysis can be applied to the results in this type of study. However, a preliminary review of the information gathered to date reveals the possible indication of meaningful trends. Table 8 shows the number of species of trees, shrubs, and herbaceous plants present in the grids in 1969, 1970, 1971, and 1972.

It also shows the number of individuals for these plant types. Some plants are more easily tallied as clumps or patches (taking area covered into consideration) and these have also been listed in addition to the number of individuals. Mosses, grasses, and sedges etc. have not always been species-identified, therefore, only the number of clumps or patches of this group has been listed for each year. The following points show the general trends observed for the plant populations present in these grids:

- (1) The number of species on all grids does not fluctuate to any degree from year to year.
 - (2) In plots 3, 4, and 8 there has been a large influx of tree seedlings from 1971 to 1972.
 - (3) The number of shrubs on most grids remains relatively stable. From 1971 to 1972 there were large increases in the number of shrubs at plot 3, grid 1; plot 5, grid 2; and plot 7, grid 2. The only grid registering a large decrease was plot 4, grid 2.
 - (4) The number of individuals or clumps of herbaceous plants maintained the status gained in 1970 and 1971. There were mixed increases or decreases which do not appear to be significant or show any trend from 1971 to 1972.
 - (5) The grass, sedge, moss, and lichen populations are relatively steady in all grids.
- (c) Chemical Analysis of 1971 Vegetation and Soil Samples

The chemical analysis of the samples collected in 1972 is still in progress at the time of writing this report. However the 1970 and 1971 data have been compiled and subjected to statistical analysis. Table 9 shows the results of the chemical analyses for vegetation and soil sampled at the eight study plots. The table of analysis of variance (Table 10, F-Values) shows that for total sulphur, arsenic, iron, and zinc the differences between the species were significant at the 1% level for both the 1970 and 1971 collections. This is the expected result since the foliage from one species would contain greater or smaller amounts of a given element than that of another species. The table of analysis of variance also shows that for these same elements, their concentrations in the vegetation are significantly different at the 1% level from station to station for both 1970 and 1971. In most cases plots 1 to 3 are significantly higher than the remainder. From Table 9 it can be seen that the arsenic levels are lower in 1971 while the iron levels are

considerably higher. Only at plot 1 are the zinc levels elevated for white birch and trembling aspen. The total sulphur levels are similar from 1970 to 1971 and are elevated (compared to the controls) from plot 1 to plot 4 for most species. For total sulphur, arsenic, and iron, the levels in the vegetation decrease with increasing distance from the sinter plant.

From Table 9 it can be seen that in the soil, the total sulphur, arsenic, and iron levels are elevated mainly at plots 1 and 2.

(d) Lead Peroxide Candle Survey

The values of sulphur recorded on the lead peroxide candles set out at each of the plots, expressed as $\text{mgm SO}_3/100 \text{ cm}^2/\text{day}$, are shown in Table 11. The Ontario sulphation criterion for desirable ambient air quality is $0.4 \text{ mgm SO}_3/100 \text{ cm}^2/\text{day}$. The values registered at plots 1, 2, and 3 are consistently higher than this **criterion**. This is also the region where the most extensive SO_2 injury to vegetation is located. The values registered at plots 4, 5, and 6 are within the **criterion**, but still higher than the background levels recorded at the control plots 7 and 8.

The average concentration of total sulphur (%) in the vegetation collected at each plot was plotted against the average sulphation rate (June, July, and August) for the lead peroxide candles, for the 1970 and 1971 growing seasons. From the resulting straight-line relationships (Figs. 4&5) the regression equations were calculated and the correlation coefficients were obtained (Table 12). The relationship between total sulphur (%) in the vegetation and the candle sulphation rate was significant at the 5% level ($r = 0.84$) in 1970 and the 1% level ($r = 0.96$) in 1971, where r is the correlation coefficient.

These close correlations confirm earlier statements that the higher incidence of injury, especially at plots 1 and 2 is the result of sulphur dioxide fumigations and that the high levels of sulphur in the vegetation are related to increased concentrations of sulphur dioxide in the ambient air.

IV. Conclusion

From the above data, it can be seen that most parameters are closely correlated to the area designations for the Fume Damage Area. At plots 1 and 2, in the Total Kill area, the sulphation rate, injury to vegetation by SO_2 , deterioration of the crown conditions, and contamination of the vegetation and soil by sulphur, arsenic, and iron are exceedingly high. In the Heavy Kill (plots 3 and 4) and the Light

Damage (plots 5 and 6) areas, the levels of these parameters decrease accordingly with increased distance from the sinter plant. Continued heavy fumigations of the area northeast of the sinter plant will lead to a further deterioration of the environment, especially in the Total Kill area (plots 1 and 2).

In 1961, the Algoma Ore Division switched to the use of low sulphur content ore during the growing season. This has resulted in an improved situation with regard to vegetation injury and growth, especially in the Heavy Kill area. In 1969 and 1970, prolonged shut-down periods enhanced the previous effect and this was manifested in reduced vegetation injury, lower sulphation rates, and improved crown conditions. In 1971 and 1972 however, a return to full production also resulted in a return to high sulphation rates, increased vegetation injury and declining crown conditions of the trees. This is an indication that further abatement measures will be required to produce the type of effect such as that noted in 1969 and 1970.

Vegetation sampling and air monitoring will be continued through the 1973 growing season and a close surveillance of the forest communities will be maintained to determine the effects of the sinter plant operation on the environment in the Wawa area.

V. Acknowledgments

The authors wish to express their appreciation to Dr. S. N. Linzon, Chief of the Phytotoxicology Section, Air Management Branch for his advice and supervision; to Mr. D. Ogner for compiling the SO₂ data; to Mr. H. Griffin and the staff of the Ministry of Natural Resources at Wawa for arranging transportation and assisting in the sampling; to Messrs A. W. Hill and P. J. Temple for assistance given in examining the Wawa area vegetation; to Mr. A. C. Rayner and Mr. Ron Wills and the staff of the Air Laboratory for analysis of samples; to Mr. B. Chai for statistical analysis of data; to Mr. D. Stewart of the Algoma Ore Corporation for furnishing production and meteorological data; and to Mrs. J. Springer for secretarial assistance. The contributions and cooperation of these people made possible the presentation of this report.

VI. APPENDIX

Fig. 1.

Vegetation Study Plots and
Autometer Locations

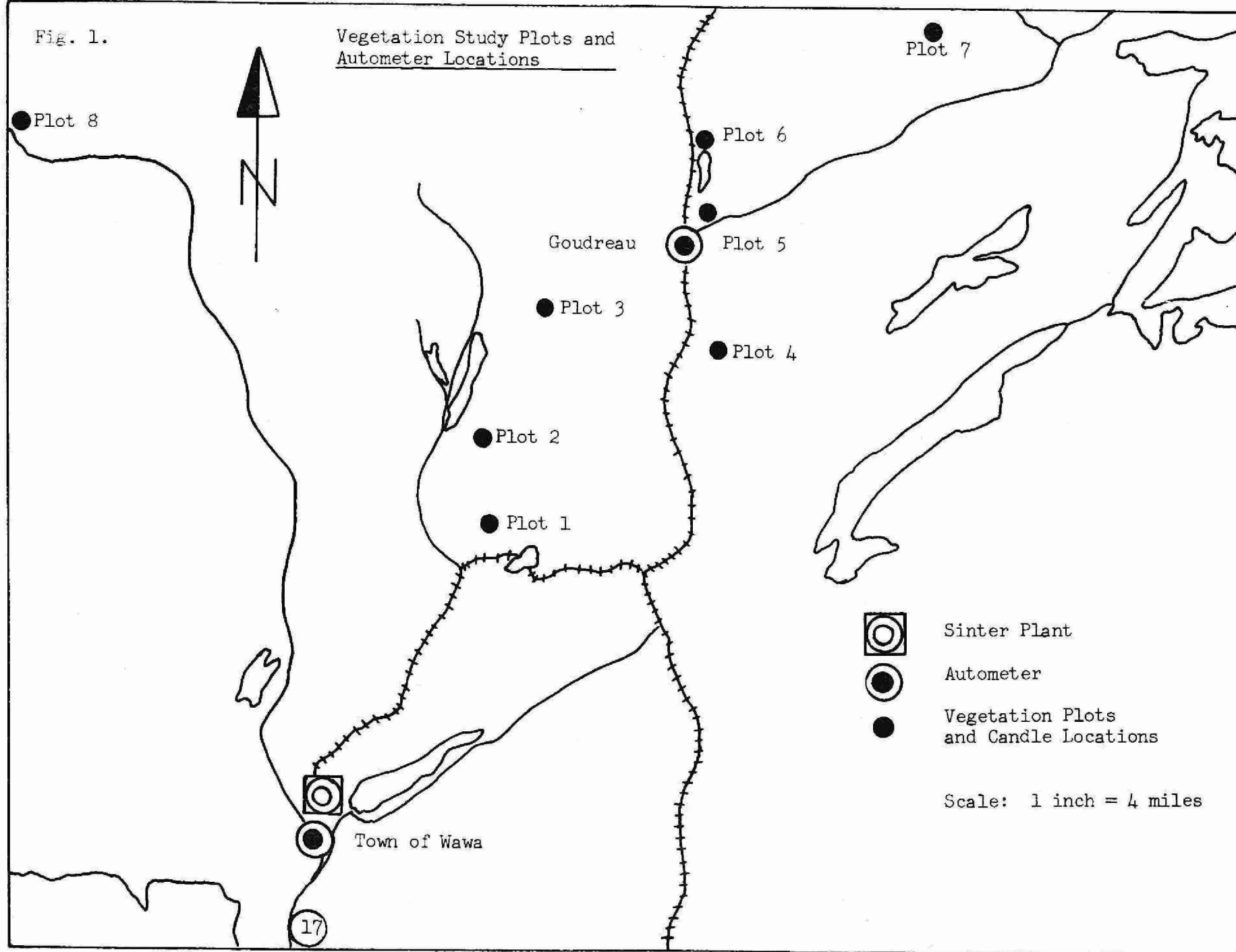


Fig. 2.

Relationship between Ore Feed and Sulphur Content of Ore 1961-1972

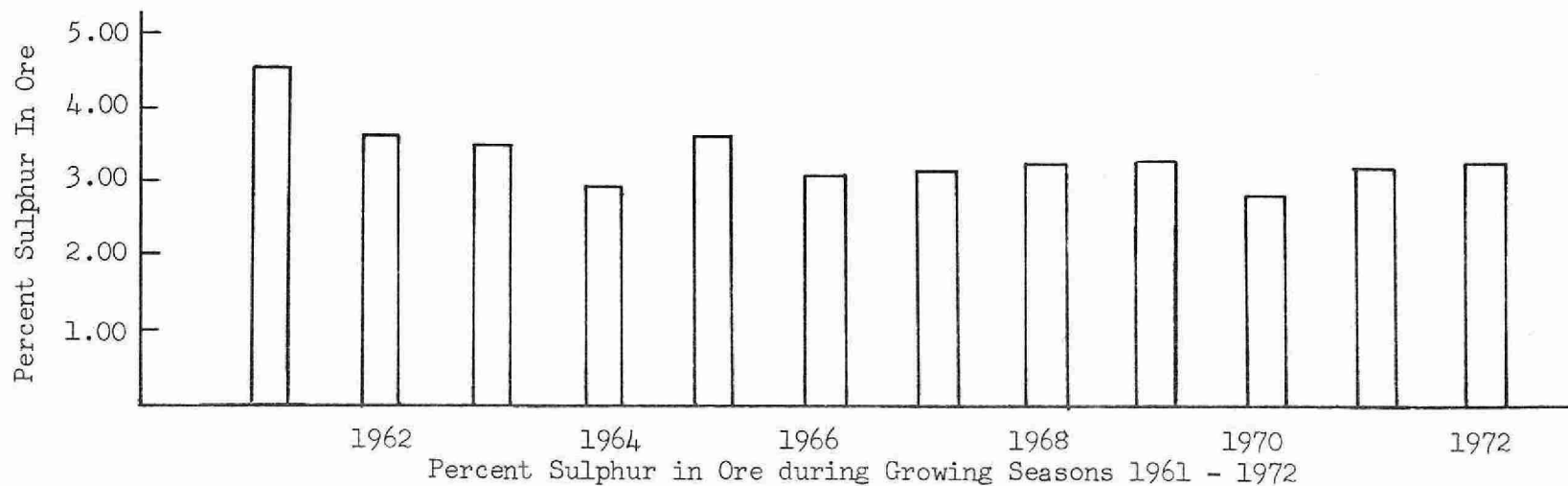
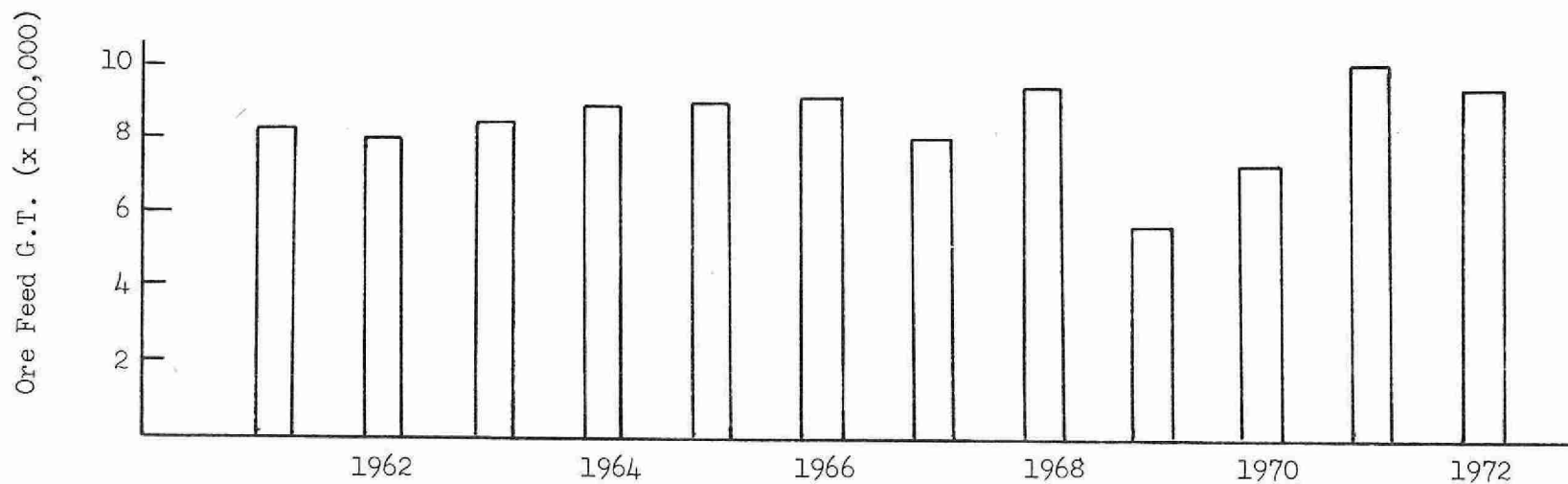
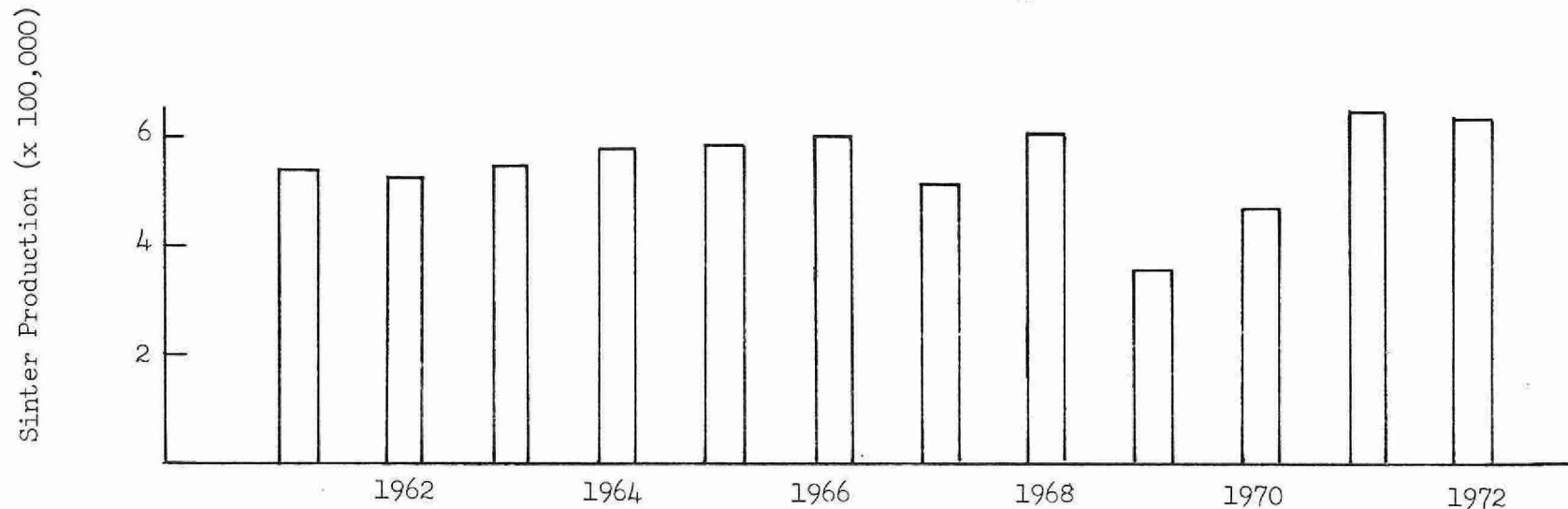
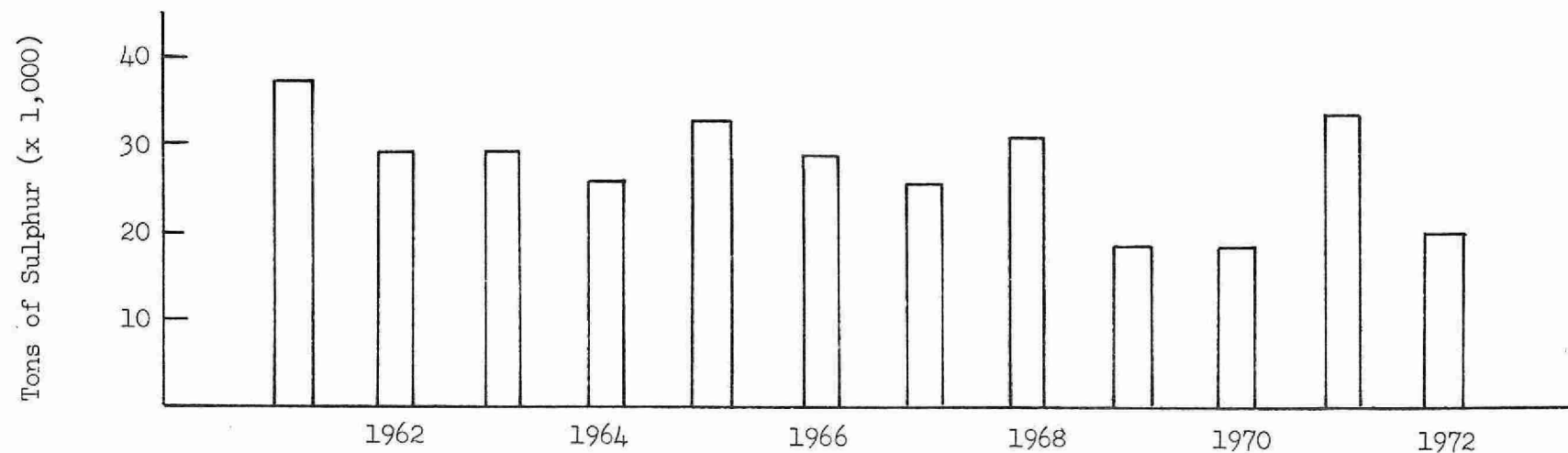


Fig. 3.

Relationship between Sinter Production and SO_2 Emissions at Wawa 1961-1972



Sinter Production during Growing Seasons 1961-1972



Tons of Sulphur lost as SO_2 during Growing Season

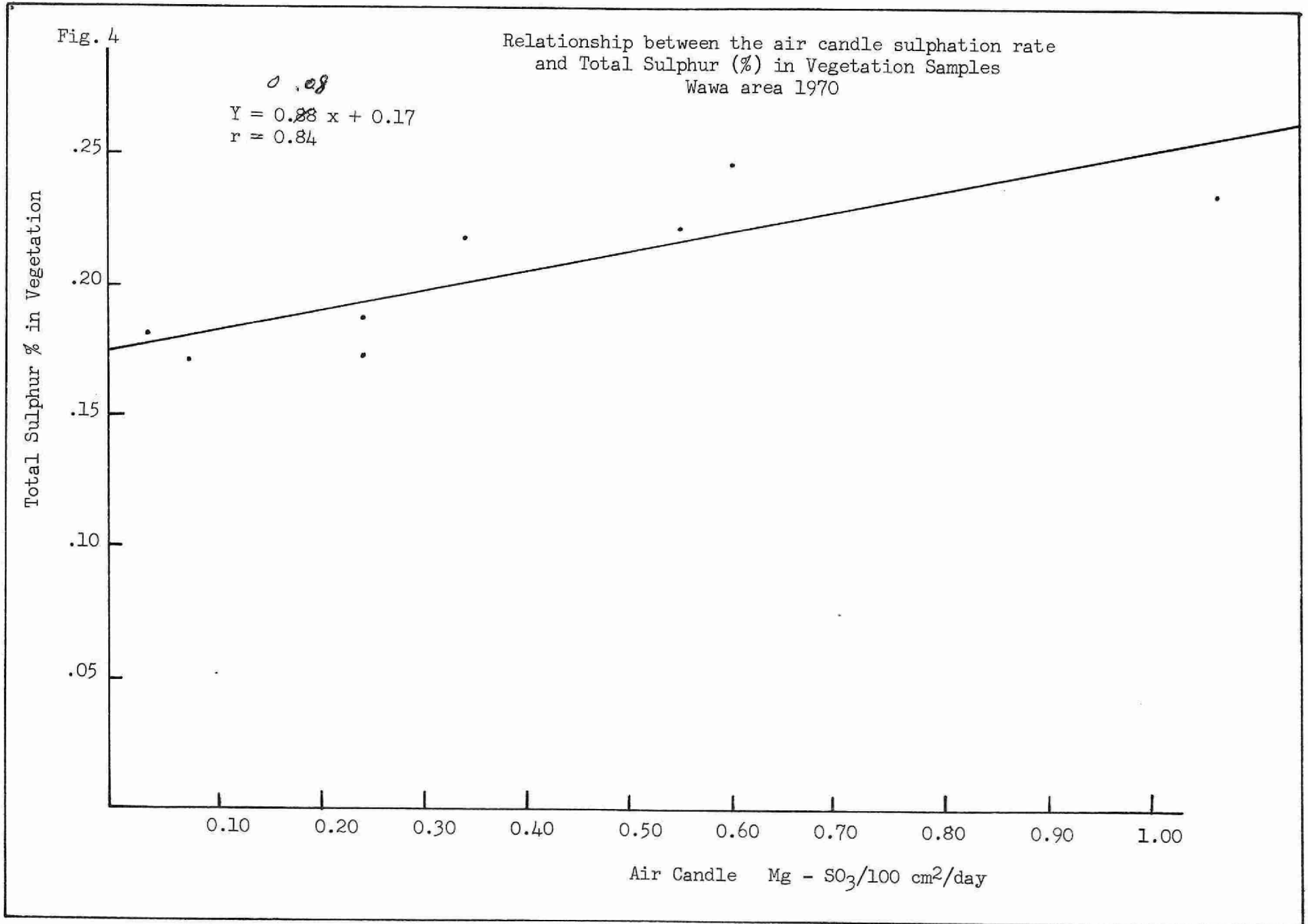


Fig. 5

Relationship between the air candle sulphation rate
and Total Sulphur (%) in Vegetation Samples
Wawa area 1971

$$r = 0.95$$
$$Y = 0.14x + 0.23$$

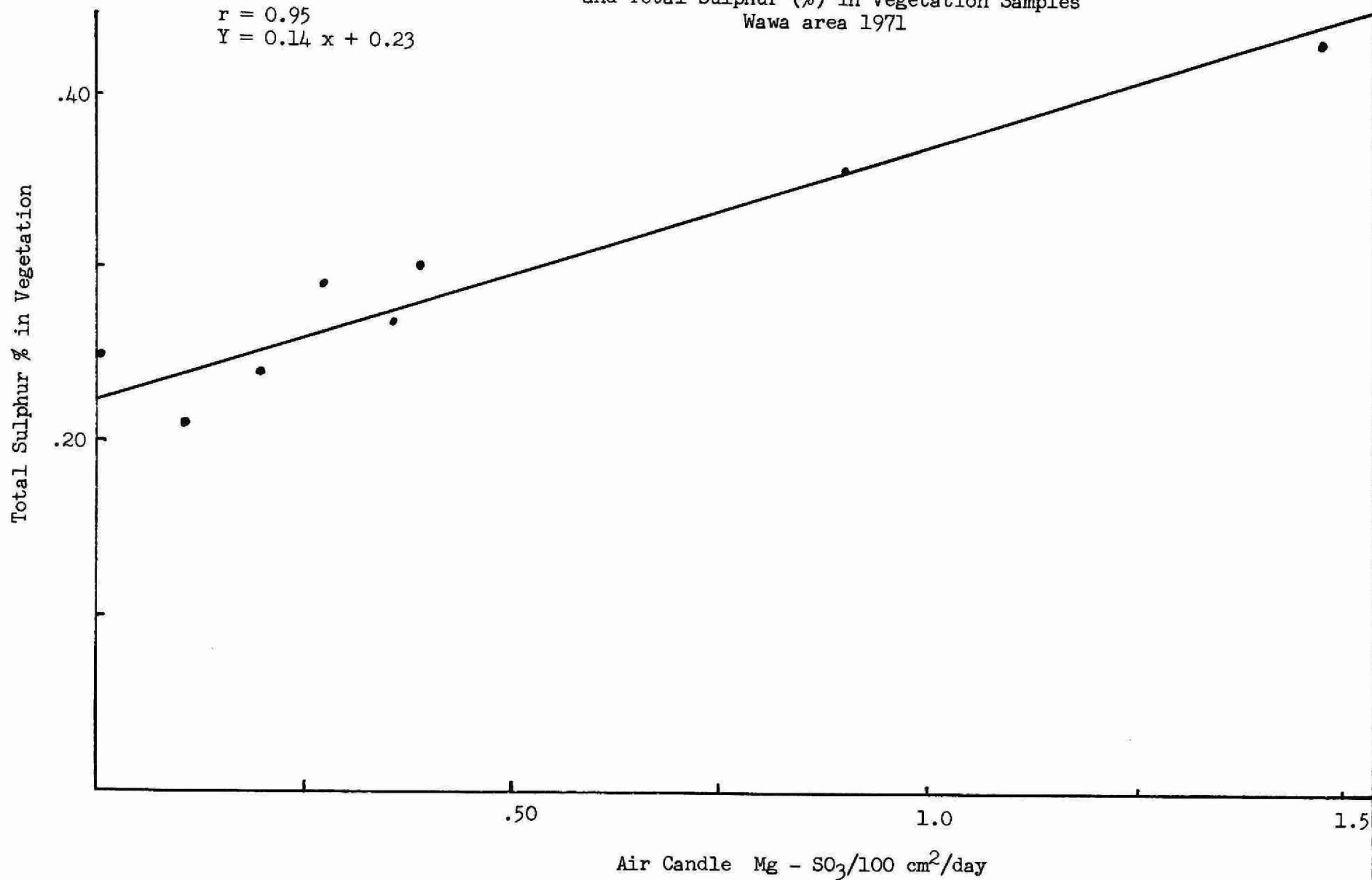


Table 1: Summary of Sulphur Dioxide data recorded in the town of Wawa during
1969, 1970, 1971, 1972

Year	Total sampling Time (hrs.)	Zero readings		SO2 readings		Max. $\frac{1}{2}$ hour conc. (ppm)	Average ppm for	
	hrs.	%	hrs.	%	SO2 periods only		Total period	
----- June -----								
1969	152.0	150.0	98.7	2.0	1.3	0.35	.17	.01
1970	651.0	634.5	97.4	16.5	2.5	0.48	.09	.01
1971	537.0	524.0	97.5	13.0	2.4	1.73	.26	.01
1972	535.5	526.5	98.3	9.0	1.7	0.40	.05	.01
----- July -----								
1969	744.0	726.0	97.6	18.0	2.4	0.14	.05	.01
1970	744.0	740.5	99.6	3.5	0.4	0.10	.06	.01
1971	743.0	727.0	97.8	16.0	2.1	0.72	.10	.01
1972	738.0	724.5	98.2	13.5	1.8	0.26	.05	.01
----- August -----								
1969	744.0	744.0	100.0	0.0	0.0	0.00	.00	.00
1970	744.0	728.0	97.8	16.0	2.2	1.22	.25	.01
1971	725.0	712.5	98.2	12.5	1.7	0.63	.20	.01
1972	739.0	706.5	95.6	32.5	4.4	1.22	.09	.01

Table 1 (cont'd): Summary of Sulphur Dioxide data recorded in the town of Wawa during
1969, 1970, 1971, 1972

Year	Total sampling Time (hrs.)	Zero readings		SO ₂ readings		Max. ½ hour conc. (ppm)	Average ppm for SO ₂ periods Total	
	hrs.	%	hrs.	%	only		period	
----- September -----								
1969	744.0	744.0	100.0	0.0	0.0	0.00	.00	.00
1970	720.0	702.5	97.6	17.5	2.4	0.38	.12	.01
1971	183.0	175.5	95.9	7.5	4.0	1.84	.51	.02
1972	418.5	403.0	96.3	15.5	3.7	0.39	.11	.01
----- October -----								
1969	512.5	512.5	100.0	0.0	0.0	0.00	.00	.00
1970	488.0	462.0	94.7	26.0	5.3	0.78	.15	.01
1971	471.5	461.5	97.8	10.0	2.0	1.06	.22	.01
1972	611.5	558.0	91.3	53.5	8.7	2.03	.39	.04
----- Season -----								
1969	2872.5	2852.5	99.3	20.0	0.7	0.35	.06	.01
1970	3618.5	3531.0	97.6	87.5	2.4	1.22	.16	.01
1971	2658.5	2600.5	97.8	59.0	0.2	1.84	.23	.01
1972	3214.0	3085.0	96.0	129.0	4.0	2.03	.21	.01

Table 2:

Summary of SO₂ data collected at Wawa during the daylight hours 1972

Month	No. of operative days	No. of days with positive SO ₂ readings	Max. daytime $\frac{1}{2}$ hr. conc. (ppm)	Max. Intensity*	Av. Intensity per fumigation	No. of days threshold limits were exceeded
May	8	1	0.55 (May 31)	46 (May 31)	46	0
June	24	5	0.46 (June 3)	23 (June 3)	8	0
July	31	4	0.26 (July 28)	25 (July 28)	11	0
August	31	9	1.22 (Aug. 9)	64 (Aug. 9)	21	0
September	21	4	0.39 (Sept. 22)	68 (Sept. 22)	28	0
October	26	6	1.37 (Oct. 14)	267 (Oct. 8)	133	3 (Oct. 8, 14, 17)
Season	141	29	1.37 (Oct. 14)	267 (Oct. 8)	43	3 (Oct. 8, 14, 17)

* Approximate threshold limits for vegetation injury i.e., .95 ppm for 1 hour or .55 ppm for 2 hours or .35 ppm for 4 hours or .25 ppm for 8 hours or an intensity of 100.

Table 3:

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1972

Year	S lost as SO ₂ 1000 tons	Total sampling time (hrs.)	Zero readings		SO ₂ readings		Half-hour concs. above				Max. ppm $\frac{1}{2}$ -hr.	Av. ppm for	
			hrs.	%	hrs.	%	.25 ppm		.50 ppm			SO ₂ periods only	Total period
							hrs.	%	hrs.	%			
-May-													
1961		-	-	-	-	-	-	-	-	-	-	-	-
1962		170.5	159.0	93.0	11.5	6.7	0.0	0.0	0.0	0.0	.17	.054	.004
1963		15.0	9.5	63.3	5.5	36.7	0.0	0.0	0.0	0.0	.05	.020	.007
1964		96.5	83.5	86.5	13.0	13.5	1.0	1.0	0.0	0.0	.27	.074	.010
1965		119.5	71.5	59.8	48.0	40.2	2.5	2.1	0.0	0.0	.46	.087	.035
1966		142.0	137.5	96.8	4.5	3.2	0.0	0.0	0.0	0.0	.08	.034	.001
1967		297.0	284.5	95.8	12.5	4.2	1.0	0.3	0.0	0.0	.33	.072	.003
1968		365.0	326.0	89.2	39.5	10.8	4.0	1.1	0.5	0.1	.54	.080	.009
1969		80.5	66.0	82.0	14.5	18.0	0.0	0.0	0.0	0.0	.20	.047	.008
1970		158.0	150.0	94.9	8.0	5.1	0.0	0.0	0.0	0.0	.10	.036	.002
1971		-	-	-	-	-	-	-	-	-	-	-	-
1972		128.5	106.5	82.9	22.0	17.1	0.0	0.0	0.0	0.0	.15	.044	.008
-June-													
1961	10.2	357.0	247.5	69.3	109.5	30.7	6.5	1.8	0.0	0.0	.46	.107	.033
1962	6.8	586.5	430.0	73.3	151.5	26.7	3.0	0.5	0.0	0.0	.33	.076	.020
1963	6.7	553.0	401.5	72.6	151.5	27.4	0.0	0.0	0.0	0.0	.24	.041	.011
1964	7.8	640.5	463.5	72.4	177.0	27.6	8.5	1.3	1.5	0.2	.61	.078	.022
1965	8.8	668.5	514.4	77.0	154.0	23.0	4.5	0.7	1.0	0.2	.60	.078	.018
1966	7.4	720.0	491.0	68.2	229.0	31.8	7.0	1.0	0.0	0.0	.47	.072	.023
1967	5.9	698.5	477.0	68.3	221.5	31.7	5.0	0.7	0.0	0.0	.35	.065	.021
1968	8.3	657.5	493.5	75.1	164.0	24.9	3.5	0.5	0.0	0.0	.45	.074	.019
1969	7.3	702.5	539.5	76.8	163.0	23.2	1.0	0.1	0.0	0.0	.27	.040	.009
1970	6.4	720.0	640.0	88.9	80.0	11.1	1.0	0.1	0.0	0.0	.30	.055	.006
1971	6.8	482.0	443.5	92.1	38.5	7.9	0.2	0.4	0.0	0.0	.28	.070	.006
1972	8.2	446.5	364.5	81.6	82.0	18.4	0.0	0.0	0.0	0.0	.08	.030	.006

Table 3(cont'd):

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1972

Year	S lost as SO2 1000 tons	Total sampling time (hrs.)	Zero		SO2		Half-hour concs. above				Max. ppm $\frac{1}{2}$ -hr.	Av. ppm for	
			readings		readings		.25 ppm		.50 ppm			SO2 periods only	Total period
			hrs.	%	hrs.	%	hrs.	%	hrs.	%			
-July-													
1961	9.5	722.0	579.5	80.3	142.5	19.7	16.5	2.3	0.0	0.0	0.48	.116	.023
1962	7.2	715.5	570.0	79.7	145.5	20.3	2.5	0.4	0.0	0.0	0.35	.070	.014
1963	6.2	664.0	547.0	82.4	117.0	17.6	2.0	0.3	0.0	0.0	0.31	.059	.010
1964	6.8	691.5	561.5	81.2	130.0	18.8	2.5	0.4	0.0	0.0	0.35	.063	.012
1965	7.7	707.5	581.5	82.2	126.0	17.8	1.5	0.2	0.0	0.0	0.39	.060	.011
1966	8.0	744.0	498.5	67.0	245.5	33.0	13.0	1.8	3.5	0.5	0.62	.083	.027
1967	5.6	691.5	438.5	63.3	253.5	36.7	10.5	1.5	0.0	0.0	0.39	.075	.028
1968	7.8	710.5	455.5	64.1	255.0	35.9	11.5	1.6	0.0	0.0	0.49	.074	.027
1969	6.6	742.5	579.5	78.1	163.0	21.9	3.0	0.4	0.0	0.0	0.35	.059	.013
*1970	-	711.0	683.5	96.1	27.5	3.9	1.0	0.1	0.0	0.0	0.27	.072	.003
1971	6.9	732.5	557.0	76.1	175.5	23.9	4.5	0.1	0.0	0.0	0.42	.060	.020
1972	7.4	538.5	379.0	70.4	159.5	29.6	1.0	0.2	0.0	0.0	0.21	.060	.018
-August-													
1961	7.9	743.5	623.0	83.6	120.5	16.2	5.5	0.7	0.0	0.0	0.39	.079	.013
1962	7.0	660.5	512.0	77.5	148.5	22.5	3.0	0.4	0.0	0.0	0.34	.065	.015
1963	7.0	740.5	603.5	81.5	137.0	18.5	1.0	0.1	0.0	0.0	0.33	.058	.011
1964	5.2	681.5	624.0	91.6	57.5	8.4	0.0	0.0	0.0	0.0	0.21	.049	.004
1965	8.2	744.0	639.5	86.0	104.5	14.0	3.5	0.5	0.0	0.0	0.34	.083	.012
1966	7.6	732.5	652.0	89.0	80.5	11.0	0.0	0.0	0.0	0.0	0.22	.048	.005
1967	6.6	744.0	570.0	76.6	174.0	23.4	8.0	1.1	0.5	0.1	0.66	.082	.019
1968	7.4	744.0	595.0	80.0	149.0	20.0	5.0	0.7	1.0	0.1	1.13	.077	.015
*1969	0.4	744.0	741.0	99.6	3.0	0.4	0.0	0.0	0.0	0.0	0.16	.102	.001
1970	5.6	454.0	429.0	94.5	25.0	5.5	0.0	0.0	0.0	0.0	0.11	.037	.002
1971	6.9	724.5	641.0	88.4	83.5	11.6	2.5	0.0	0.0	0.0	0.48	.080	.010
1972	7.5	626.0	383.5	61.3	242.5	38.7	1.0	0.2	0.0	0.0	0.32	.022	.008

** Plant shutdown from July 4th, 1970 to August 3rd, 1970

* 1969 Shutdown from August 2nd, to November 10th.

Table 3 (cont'd):

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1972

Year	S lost as SO2 1000 tons	Total sampling time (hrs.)	Zero		SO2		Half-hour concs. above				Max. ppm 1/2-hr.	Av. ppm for	
			readings		readings		.25 ppm		.50 ppm			SO2 periods only	Total period
			hrs.	%	hrs.	%	hrs.	%	hrs.	%			
-September-													
1961		563.0	503.5	89.4	59.5	10.6	1.0	0.2	0.0	0.0	0.34	.063	.007
1962		720.0	652.5	90.6	67.5	9.4	3.0	0.4	0.5	0.1	0.80	.078	.007
1963		581.5	460.0	79.1	121.5	20.9	8.5	1.5	0.5	0.1	0.72	.088	.018
1964		632.0	579.5	91.7	52.5	8.3	0.0	0.0	0.0	0.0	0.14	.044	.004
1965		720.0	666.0	92.5	54.0	7.5	0.5	0.1	0.0	0.0	0.27	.048	.004
1966		720.0	660.0	91.7	60.0	8.3	0.0	0.0	0.0	0.0	0.21	.050	.004
1967		674.5	561.0	83.2	113.5	16.5	6.5	1.0	0.5	0.1	0.53	.091	.015
1968		720.0	661.0	91.8	59.0	8.2	0.5	0.0	0.0	0.0	0.31	.051	.004
*1969		720.0	720.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	.000	.000
1970		678.5	649.0	95.6	29.5	4.4	0.5	0.0	0.0	0.0	0.31	.049	.002
1971		343.0	325.5	94.9	17.5	5.1	0.0	0.0	0.0	0.0	0.19	.040	.002
1972		671.5	546.0	81.3	125.5	18.7	0.0	0.0	0.0	0.0	0.10	.017	.003
-October-													
1961		286.0	260.5	91.1	25.5	8.9	0.5	0.2	0.0	0.0	0.32	.058	.005
1962		276.5	233.0	84.6	42.5	15.4	2.5	0.9	0.5	0.2	0.52	.080	.012
1963		321.5	234.5	72.9	87.0	27.1	8.5	2.6	0.5	0.2	0.52	.110	.030
1964		326.0	317.5	97.4	08.5	2.6	0.0	0.0	0.0	0.0	0.13	.048	.001
1965		322.0	312.0	96.9	10.0	3.1	0.0	0.0	0.0	0.0	0.13	.038	.001
1966		384.0	374.0	97.4	10.0	2.6	0.0	0.0	0.0	0.0	0.14	.055	.001
1967		388.0	330.0	85.0	58.0	15.0	0.0	0.0	0.0	0.0	0.16	.044	.006
1968		396.0	339.0	85.6	57.0	14.4	1.5	0.4	0.0	0.0	0.31	.056	.008
*1969		516.5	516.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	.000	.000
1970		468.0	439.0	93.8	29.0	6.2	0.0	0.0	0.0	0.0	0.16	.034	.002
1971		225.0	220.0	97.7	5.0	2.3	0.0	0.0	0.0	0.0	0.13	.040	.001
1972		-	-	-	-	-	-	-	-	-	-	-	-

* Plant shutdown from August 2nd, to November 10th, 1969

Table 3 (cont'd):

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1972

S lost as SO2 1000 tons	Total sampling time (hrs.)	Zero readings hrs. %		SO2 readings hrs. %		Half-hour concs. above					Max. ppm $\frac{1}{2}$ -hr.	Av. ppm for	
						.25 ppm		.50 ppm				SO2 periods only	Total period
						hrs.	%	hrs.	%	hrs.			
- Season -													
1961	36.5**	2671.5	2214.0	82.9	457.5	17.1	30.0	1.1	0.0	0.0	0.48	.094	.016
1962	28.7	3128.5	2556.5	81.7	572.0	18.3	14.0	0.4	1.0	0.1	0.80	.072	.013
1963	28.8	2875.5	2256.0	78.5	619.5	21.5	20.0	0.7	1.0	0.1	0.72	.067	.014
1964	26.1	3068.0	2529.5	85.7	438.5	14.3	12.0	0.4	1.5	0.1	0.61	.065	.009
1965	32.2	3281.5	2785.0	84.9	496.5	15.1	12.5	0.4	1.0	0.1	0.60	.071	.011
1966	28.8	3442.5	2813.0	81.7	629.5	18.3	20.0	0.6	3.5	0.1	0.62	.070	.013
1967	25.2	3493.5	2660.5	76.2	833.0	23.8	31.0	0.9	1.0	0.03	0.66	.074	.018
1968	30.8	3593.5	2870.0	79.9	723.5	20.1	26.0	0.7	1.5	0.04	1.13	.072	.014
1969	18.5	3506.0	3162.5	90.2	343.5	9.8	4.0	0.1	0.0	0.00	0.35	.050	.005
1970	18.1	3189.5	2990.5	93.8	199.0	6.2	2.5	0.8	0.0	0.00	0.31	.050	.003
1971	32.7	2507.0	2187.0	87.3	320.0	12.7	9.0	0.4	0.0	0.00	0.48	.071	.009
1972	30.3	2411.0	1779.5	73.8	631.5	26.2	2.0	0.8	0.0	0.00	0.32	.030	.008

Operative Periods

1961 June 15 - October 16
 1962 May 24 - October 12
 1963 May 31 - October 14
 1964 May 27 - October 14
 1965 May 26 - October 14
 1966 May 25 - October 16

1967 May 17 - October 17
 1968 May 15 - October 17
 1969 May 28 - October 22
 1970 May 20 - October 20
 1971 June 10 - October 14
 1972 May 24 - September 30

** May 16 - September 15

† Plant shutdown from August 2nd, to November 10th, 1969

†† Plant shutdown from July 4th, to August 3rd, 1970

Table 4:

Summary of SO₂ data collected at Goudreau during the daylight hours 1972

Month	No. of operative days	No. of days with positive SO ₂ readings	Max. daytime $\frac{1}{2}$ hr. conc. (ppm)	Max. Intensity*	Av. Intensity per fumigation	No. of days threshold limits were exceeded
May	8	6	0.15 (May 31)	34 (May 31)	12	0
June	25	10	0.08 (June 3)	18 (June 3)	9	0
July	30	20	0.24 (July 23)	60 (July 4)	20	0
August	29	24	0.36 (Aug.10)	35 (Aug.10)	8	0
September	29	27	0.14 (Sept. 9)	16 (Sept. 1)	4	0
Season	121	87	0.36 (Aug.10)	60 (July 4)	10	0

* Approximate threshold limits for vegetation injury i.e., .95 ppm for 1 hour or .55 ppm for 2 hours or .35 ppm for 4 hours or .25 ppm for 8 hours or an intensity of 100.

Table 5:

Percentage frequencies of wind directions at Wawa**

Wind	May		June		July		August		September		Season (May - Sept.)	
	Mean* %	1972 %	Mean* %	1972 %	Mean* %	1972 %	Mean* %	1972 %	Mean* %	1972 %	Mean* %	1972 %
N	15.8	14.0	15.1	10.8	16.0	8.6	19.4	9.4	17.9	14.7	17.3	10.8
NE	9.6	27.0	10.9	33.1	5.8	10.0	8.8	17.5	9.4	12.5	8.9	20.1
E	1.5	2.2	1.5	0.3	1.1	0.8	1.9	6.9	1.9	1.4	1.8	2.5
SE	2.6	1.2	1.2	0.4	0.9	0.7	2.0	1.1	2.8	0.6	2.2	0.8
S	17.9	2.6	18.5	3.1	23.0	5.2	14.5	3.6	13.2	2.5	17.0	3.6
SW	31.0	29.2	32.5	38.1	30.9	57.0	27.7	36.4	28.7	37.5	29.5	41.1
W	2.5	11.8	2.1	13.2	2.1	15.6	2.9	13.2	5.3	26.1	3.7	15.1
NW	5.9	1.5	3.7	1.0	3.6	1.6	5.0	1.8	8.6	4.7	5.7	1.9
C	8.3	0.0	7.8	0.0	8.2	0.0	9.6	0.0	9.3	0.0	8.1	0.0
Inop	4.9	10.5	6.7	0.0	8.4	0.5	8.2	10.1	2.9	0.0	5.8	4.1
Prevailing Wind	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW

* 5 Year Mean

** Meteorological data supplied by Algoma Ore Division The Algoma Steel Corporation, Limited

Table 6:

Production and Emissions at Wawa during 1961-1972 Growing Seasons*

Year	Ore Feed (G.T.)	% Sulphur In Ore	Sinter Produced From Ore (G.T.)	Sulphur Lost As SO ₂ (G.T.)
1961	816,311	4.55	575,825	36,479
1962	800,697	3.66	540,700	28,657
1963	832,069	3.53	545,445	28,837
1964	893,990	3.00	562,637	26,087
1965	891,818	3.70	620,249	32,194
1966	923,785	3.19	628,930	28,790
1967	794,128	3.24	543,377	25,223
1968	926,734	3.38	609,406	30,822
1969	554,339	3.39	364,554	18,479
1970	733,630	3.00	434,726	18,069
1971	1,002,012	3.35	654,892	32,723
1972	926,164	3.33	622,332	30,342

* Production Data supplied by the Algoma Steel Corporation Ltd.

Table 7:

Summary of the Changes in "Crown Condition" of the trees and Shrubs on the Wawa Vegetation Plots from 1969 to 1970 from 1970 to 1971, and from 1971 to 1972

<u>Plot No.</u>	<u>Location</u>	<u>Date</u>	No. of Trees or Shrubs where the Crown Condition has		
			<u>Improved</u>	<u>Declined</u>	<u>Remained Unchanged</u>
1	10 m. NE	1969 to 1970	2	7	11
		1970 to 1971	4	6	9 (& 1 dead)
		1971 to 1972	4	2	13 (& 2 dead)
2	12 m. NE	1969 to 1970	0	5	15
		1970 to 1971	9	2	8 (& 1 removed
		1971 to 1972	3	4	12 by beaver)
3	16 m. NE	1969 to 1970	0	9	11
		1970 to 1971	5	1	14
		1971 to 1972	4	3	13
4	19 m. NE	1969 to 1970	1	5	14
		1970 to 1971	6	0	14
		1971 to 1972	0	3	17
5	22 m. NE	1969 to 1970	5	3	12
		1970 to 1971	4	1	15
		1971 to 1972	5	3	12
6	24 m. NE	1969 to 1970	2	6	12
		1970 to 1971	4	0	16
		1971 to 1972	1	3	16
7 (control)	38 m. NE	1969 to 1970	2	4	14
		1970 to 1971	4	5	11
		1971 to 1972	1	4	14 (& 1 dead)
8 (control)	35 m. NE	1969 to 1970	0	4	16
		1970 to 1971	11	2	7
		1971 to 1972	8	2	10

Table 8:

Summary of the Ground Flora Populations in the Grids adjacent to
the Wawa Vegetation Plots in 1969, 1970, 1971, and 1972

Plot No.	Location	Grid No.		Trees				Shrubs				Herbaceous plants				Grasses, Sedges, Mosses, Lichens			
			Year	'69	'70	'71	'72	'69	'70	'71	'72	'69	'70	'71	'72	'69	'70	'71	'72
1	10 m. NE	1	No. of Species	1	1	1	1	4	4	4	5	6	8	9	7	-	-	-	-
			No. of Individ.	12	8	5	7	7	9	6	8	287	338	407	418	-	-	-	-
			No. of Clumps	-	-	-	-	19	27	22	18	1	5	4	-	-	-	-	-
		2	No. of Species	2	2	2	2	6	6	6	4	7	9	9	8	-	-	-	-
			No. of Individ.	2	2	2	2	7	7	11	8	166	264	265	208	3	2	2	1
			No. of Clumps	-	-	-	-	-	-	-	-	2	4	2	-	8	12	20	23
2	12 m. NE	1	No. of Species	1	1	1	1	2	2	2	2	5	5	5	5	-	-	-	-
			No. of Individ.	11	8	4	4	2	1	-	1	221	371	333	421	-	-	-	-
			No. of Clumps	-	-	-	-	24	42	28	18	7	40	44	26	4	10	9	13
		2	No. of Species	1	1	1	4	4	4	4	4	6	6	6	6	-	-	-	-
			No. of Individ.	1	2	1	8	4	9	7	8	226	356	376	254	-	-	-	-
			No. of Clumps	-	-	-	15	23	29	28	15	12	12	8	10	14	15	18	26
3	16 m. NE	1	No. of Species	2	2	1	1	5	5	5	5	6	7	7	7	-	-	-	-
			No. of Individ.	7	7	4	54	17	24	22	46	186	250	231	218	-	-	-	1
			No. of Clumps	-	-	-	-	7	11	7	3	8	40	21	25	29	74	48	53
		2	No. of Species	3	3	3	4	2	3	3	3	3	3	5	4	-	-	-	-
			No. of Individ.	4	3	3	6	1	2	2	2	223	258	168	218	-	-	-	1
			No. of Clumps	-	-	-	-	12	23	25	25	-	-	1	-	-	-	2	-

Table 8 (cont'd):

Summary of the Ground Flora Populations in the Grids adjacent
to the Wawa Vegetation Plots in 1969, 1970, 1971, and 1972

Plot No.	Location	Grid No.		Trees				Shrubs				Herbaceous plants				Grasses, Sedges, Mosses, Lichens			
			Year	'69	'70	'71	'72	'69	'70	'71	'72	'69	'70	'71	'72	'69	'70	'71	'72
4	19 m. NE	1	No. of Species	1	1	-	-	4	4	4	5	4	5	5	5	-	-	-	-
			No. of Individ.	1	1	-	-	24	31	26	32	384	692	436	556	-	-	-	-
			No. of Clumps	-	-	-	-	76	54	51	31	-	-	-	-	1	8	10	10
		2	No. of Species	3	3	3	3	2	2	3	3	3	6	6	5	-	-	-	-
			No. of Individ.	38	37	18	61	3	2	2	2	54	328	253	235	-	-	-	-
			No. of Clumps	-	-	-	-	96	98	84	42	2	2	2	1	16	47	36	41
5	22 m NE	1	No. of Species	3	3	3	2	3	3	3	3	6	6	6	6	-	-	-	-
			No. of Individ.	15	15	8	6	7	5	5	6	62	103	108	86	39	24	18	36
			No. of Clumps	-	-	-	-	31	48	48	44	5	9	6	15	15	22	25	25
		2	No. of Species	2	2	2	2	4	4	4	3	5	5	5	4	-	-	-	-
			No. of Individ.	3	3	2	5	3	3	1	13	66	152	78	125	-	-	-	3
			No. of Clumps	-	-	-	-	8	11	23	20	22	14	41	22	11	10	19	17
6	24 m NE	1	No. of Species	1	-	-	-	3	4	3	3	4	5	5	5	-	-	-	-
			No. of Individ.	2	-	-	-	2	3	1	1	42	101	87	74	-	-	-	-
			No. of Clumps	-	-	-	-				21	-	-	-	-	2	2	4	1
		2	No. of Species	-	-	-	-	4	4	4	4	3	4	5	4	-	-	-	-
			No. of Individ.	-	-	-	-	6	10	11	13	49	77	74	78	-	-	-	2
			No. of Clumps	-	-	-	-	13	16	16	21	-	-	-	-	7	4	5	4

Table 8 (cont'd):

Summary of the Ground Flora Populations in the Grids adjacent
to the Wawa Vegetation Plots in 1969, 1970, 1971, and 1972

Plot No.	Location	Grid No.		Trees				Shrubs				Herbaceous plants				Grasses, Sedges, Mosses, Lichens			
		1	Year	'69	'70	'71	'72	'69	'70	'71	'72	'69	'70	'71	'72	'69	'70	'71	'72
7 (control)	38 m. NE	1	No. of Species	2	2	2	2	2	2	2	2	7	7	6	5	-	-	-	-
			No. of Individ.	13	10	10	11	10	7	8	8	340	377	373	292	-	-	-	-
			No. of Clumps	-	-	-	-	2	2	2	2	1	-	-	-	3	7	7	18
		2	No. of Species	4	4	4	2	3	3	3	4	7	7	7	6	-	-	-	-
			No. of Individ.	29	17	14	3	6	7	7	28	193	236	236	92	-	-	-	-
			No. of Clumps	-	-	-	-	1	2	2	1	-	-	-	1	10	32	22	32
8 (control)	35 m NW	1	No. of Species	2	2	3	3	1	2	2	2	3	3	3	3	-	-	-	-
			No. of Individ.	10	10	9	24	1	2	1	1	117	159	148	165	-	-	-	-
			No. of Clumps	-	-	-	2	-	-	-	-	-	-	-	-	40	43	37	25
		2	No. of Species	2	2	2	3	1	1	1	1	6	7	7	7	-	-	-	-
			No. of Individ.	10	8	5	15	-	-	-	-	147	148	123	107	16	12	13	4
			No. of Clumps	-	-	-	-	18	13	11	12	1	2	1	1	11	12	12	14

Table 9:

Concentrations of Various Chemical Elements in Vegetation collected at the Eight Study Plots in the Wawa area in 1970 and 1971 (Average of four (1970) and three (1971) monthly collections)

Species: Trembling Aspen		<u>Elements</u>							
<u>Plot No.</u>	<u>Location</u>	ToS % ppm		As ppm		Fe ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971
1	10 m. NE	<u>.31</u>	<u>.57</u>	<u>22.8</u>	<u>9.1</u>	89	<u>124</u>	<u>380</u>	<u>377</u>
2	12 m. NE	-	-	-	-	-	-	-	-
3	16 m. NE	.22	.34	<u>5.8</u>	2.2	56	71	<u>300</u>	250
4	19 m. NE	-	-	-	-	-	-	-	-
5	22 m. NE	.25	.35	3.3	2.5	53	71	264	225
6	24 m. NE	.22	.34	<u>5.8</u>	2.3	60	90	<u>307</u>	235
*7	38 m. NE	.21	.23	1.9	1.5	57	72	190	168
*8	35 m. NW	.21	.36	0.7	0.9	51	87	151	178
Trembling Aspen not available at Plots 2 and 4									
Species: White Birch									
<u>Plot No.</u>	<u>Location</u>	ToS % ppm		As ppm		Fe ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971
1	10 m. NE	<u>.25</u>	<u>.49</u>	<u>19.6</u>	<u>9.0</u>	51	<u>325</u>	226	<u>330</u>
2	12 m. NE	<u>.24</u>	<u>.34</u>	<u>14.1</u>	<u>6.2</u>	65	<u>155</u>	240	<u>253</u>
3	16 m. NE	.28	.28	<u>8.0</u>	3.1	38	115	252	270
4	19 m. NE	<u>.24</u>	<u>.32</u>	<u>9.9</u>	3.8	64	120	188	197
5	22 m. NE	.18	<u>.31</u>	<u>7.5</u>	3.0	55	96	198	290
6	24 m. NE	.19	<u>.26</u>	<u>6.6</u>	2.9	64	104	152	173
*7	38 m. NE	.16	.17	2.6	1.2	44	81	228	188
*8	35 m. NW	.15	.19	0.8	1.0	47	77	88	217

* Plots 7 and 8 are control plots

** Underlined values are markedly higher than control values

Table 9 (cont'd):

Concentrations of Various Chemical Elements in Vegetation collected at the Eight Study Plots in the Wawa area in 1970 and 1971 (Average of four (1970 and three (1971) monthly collections)

Species: Mountain Maple		Elements							
Plot No.	Location	ToS % ppm		As ppm		Fe ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971
1	10 m. NE	.24	<u>.35</u>	<u>18.2</u>	5.9	85	<u>229</u>	37	44
2	12 m. NE	<u>.39</u>	<u>.38</u>	<u>7.8</u>	4.6	59	<u>128</u>	43	41
3	16 m. NE	.17	<u>.28</u>	<u>5.3</u>	3.3	52	<u>133</u>	40	35
4	19 m. NE	-	-	-	-	-	-	-	-
5	22 m. NE	.24	.29	3.7	2.0	46	117	27	33
6	24 m. NE	.16	.22	3.7	1.6	46	86	37	36
*7	38 m. NE	.19	.26	1.9	1.1	58	81	45	33
*8	35 m. NW	.20	.22	0.6	0.7	69	93	33	34

Species: Showy Mountain Ash									
Plot No.	Location	ToS % ppm		As ppm		Fe ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971
1	10 m. NE	<u>.21</u>	.27	<u>15.0</u>	6.7	63	250	28	30
2	12 m. NE	<u>.23</u>	<u>.37</u>	<u>11.3</u>	4.6	39	<u>137</u>	25	21
3	16 m. NE	<u>.20</u>	<u>.27</u>	<u>6.6</u>	2.9	31	<u>117</u>	28	18
4	19 m. NE	<u>.18</u>	<u>.29</u>	<u>9.4</u>	2.5	31	<u>96</u>	24	23
5	22 m. NE	.16	-	3.5	-	-	-	18	-
6	24 m. NE	.14	.22	4.5	2.5	40	124	24	17
*7	38 m. NE	.13	.20	1.4	1.4	37	88	27	25
*8	35 m. NW	.14	.17	0.6	0.7	43	90	31	24

* Plots 7 and 8 - control plots

** Underlined values are markedly higher than control values

Table 9 (cont'd):

Concentrations of Various Chemical Elements in Vegetation and Soil collected at the Eight Study Plots in the Wawa Area in 1970 and 1971 (Average of four (1970) and three (1971) monthly collections)

Species: Forage		Elements							
Plot No.	Location	ToS % ppm		As ppm		Fe ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971
1	10 m. NE	.18	.39	8.4	4.4	62	120	37	34
2	12 m. NE	.16	<u>.43</u>	<u>4.8</u>	<u>3.3</u>	49	<u>122</u>	40	36
3	16 m. NE	.21	<u>.16</u>	<u>5.6</u>	2.4	40	<u>50</u>	37	33
4	19 m. NE	.15	.27	<u>5.1</u>	3.9	48	69	50	26
5	22 m. NE	.17	.24	<u>2.2</u>	1.7	48	87	37	31
6	24 m. NE	.16	.21	3.0	2.3	46	71	39	47
*7	38 m. NE	.16	.17	0.9	1.1	72	74	35	30
*8	35 m. NW	.21	.30	0.5	1.0	53	63	50	41

Species: Soil **									
Plot No.	Location	ToS % ppm		As ppm		Fe %		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971
1	10 m. NE	<u>.05</u>	.03	<u>56.7</u>	<u>56.5</u>	1.92	<u>2.83</u>	57	68
2	12 m. NE	<u>.05</u>	<u>.06</u>	<u>24.4</u>	<u>24.9</u>	1.92	<u>3.52</u>	23	63
3	16 m. NE	.03	.02	<u>9.6</u>	<u>6.5</u>	0.67	0.37	18	17
4	19 m. NE	.03	.02	<u>19.6</u>	<u>72.6</u>	2.20	1.83	36	37
5	22 m. NE	.03	.02	<u>6.4</u>	<u>8.4</u>	1.96	2.39	55	89
6	24 m. NE	.02	.02	4.1	6.9	1.36	1.27	21	24
*7	38 m. NE	.02	.02	2.1	4.9	0.85	0.75	24	27
*8	35 m. NW	.01	.01	0.7	2.0	0.08	0.10	3	9

* Plots 7 and 8 - control plots

** Average of two monthly collections

*** Underlined values are markedly higher than control values

Table 10:

Summary of Analysis of Variance (F- Values) for
different Chemicals in Vegetation in the Wawa
area in 1970 and 1971

<u>Chemical</u>		<u>Total</u> <u>Sulphur</u>	<u>Arsenic</u>	<u>Iron</u>	<u>Zinc</u>
<u>Sources</u> <u>of Variation</u>	<u>Year</u>				
Species	1970	15.56**	12.03**	14.15**	110.35**
	1971	4.74**	5.16**	7.74**	77.09**
Station	1970	9.35**	60.72**	6.27**	4.36**
	1971	8.68**	29.10**	10.96**	3.24**

** significant at 1% level

Table 11:

Values of Sulphur Recorded in 1970, 1971, and 1972 on the
Lead Peroxide Candles at the Vegetation Plots in the Wawa
area expressed as $\text{mgm SO}_3/100 \text{ cm}^2/\text{day}$

Plot No.	Location	June			*	July			August			Mean		
		1970	1971	1972		1970	1971	1972	1970	1971	1972	1970	1971	1972
1	10 m. NE	1.31	1.29	1.82	-	2.47	1.41		.74	.67	1.42	1.03	1.47	1.55
2	12 m. NE	.89	.95	.94	-	1.25	1.06		.34	.46	.61	.61	.88	.87
3	16 m. NE	.57	.42	.49	.15	.46	.52		-	.20	.26	.59	.36	.42
4	19 m. NE	.28	.42	.50	-	.55	.40		.23	.20	.23	.25	.39	.38
5	22 m. NE	.35	.20	.48	.12	.41	.34		-	.19	.24	.35	.26	.35
6	24 m. NE	.25	.23	.20	.09	.25	.24		-	.13	.12	.25	.20	.19
7 (control)	38 m. NE	.24	.12	.12	.07	.16	.14		.04	.08	.08	.08	.12	.11
8 (control)	35 m. NW	.03	.11	.02	.05	.01	.01		.05	.01	.03	.04	.04	.02

* Sinter plant shut down from July 4 to August 3, 1970

- Data invalid

Table 12:

The Correlation Coefficient and Regression Equation of
the Air Candle Sulphation Rate and the Total Sulphur (%)
in Vegetation Samples

Wawa 1970 and 1971

Plot No.	Distance and Direction from Sinter Plant	Average Sulphation Rate mgm SO ₃ /100 cm ² /day		Average concentration of Total Sulphur (%) in Vegetation	
		<u>1970</u>	<u>1971</u>	<u>1970</u>	<u>1971</u>
1	10 m. NE	1.03	1.48	0.24	0.44
2	12 m. NE	.61	0.88	0.25	0.36
3	16 m. NE	.57	0.36	0.22	0.27
4	19 m. NE	.25	0.39	0.19	0.30
5	22 m. NE	.35	0.26	0.22	0.30
6	24 m. NE	.25	0.20	0.17	0.25
7	38 m. NE	.08	0.12	0.17	0.21
8	35 m. NW	.04	0.04	0.18	0.26

	<u>1970</u>	<u>1971</u>	
Correlation Coefficient	r = 0.84*	r = 0.96**	**Significant at 1% level
Regression Equation	Y = 0.08x + 0.17	Y = 0.14 x + 0.23	*Significant at 5% level



(8286)

MOE/WAW/SUL/ALWB

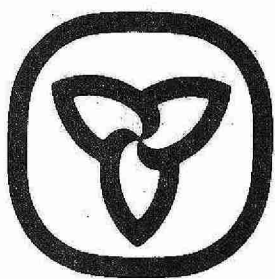
MOE/WAW/SUL/ALWB

McGovern, P C

Sulphur dioxide

(1972) - heavy metal alwb

c.1 a aa



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